Jet Propulsion Laboratory
California Institute of Technology

Photo-z calibration for Stage IV cosmology probes using fiber spectroscopy with Keck/TMT

Dan Masters (JPL/California Institute of Technology)

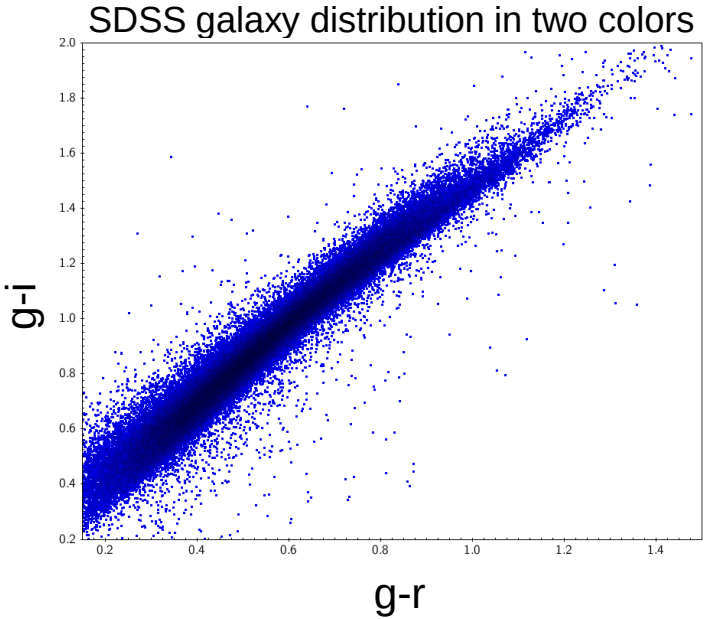
Collaborators: Peter Capak, Jason Rhodes, Shoubaneh Hemmati, Daniel Stern, Judy Cohen, Olivier Doré, WFIRST Cosmology SIT (http://www.wfirst-hls-cosmology.org)

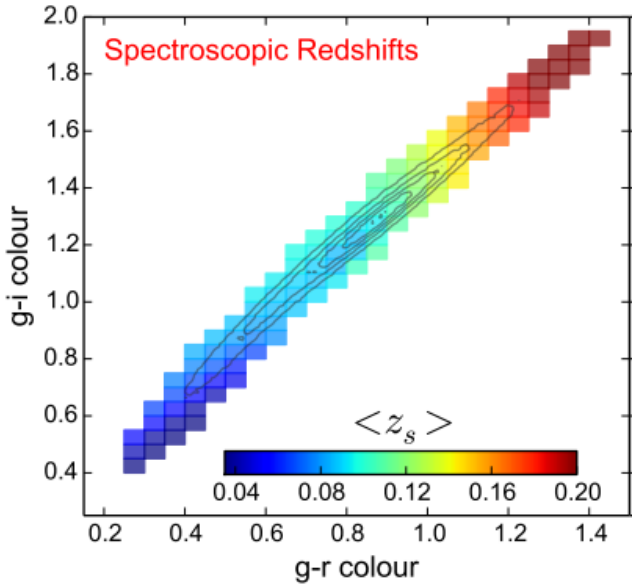
ⓒ 2018 California Institute of Technology.
Government sponsorship acknowledged.

Euclid/WFIRST/LSST photo-z calibration

- Different approaches possible
- Need to know *N*(z) distribution of ~10-20 tomographic bins to high accuracy (~0.2%)
- Combination of “direct” calibration (e.g. Masters et al. 2015) of P(z|C) relation and cluster-z (e.g. Newman 2008, Menard et al. 2013) likely
- Independent methods important to validate calibration

The empirical P(z|C) relation





Rahman et al. 2015

Photo-z's are fundamentally a mapping of galaxy colors to redshift
Color distribution of galaxies to a given depth is *limited* and *measurable*

The Self-Organizing Map

- The problem of mapping a high-dimensional dataset arises in many fields, and a number of techniques have been developed
- We adopt the widely-used Self-Organizing Map (SOM), or Kohonen Map

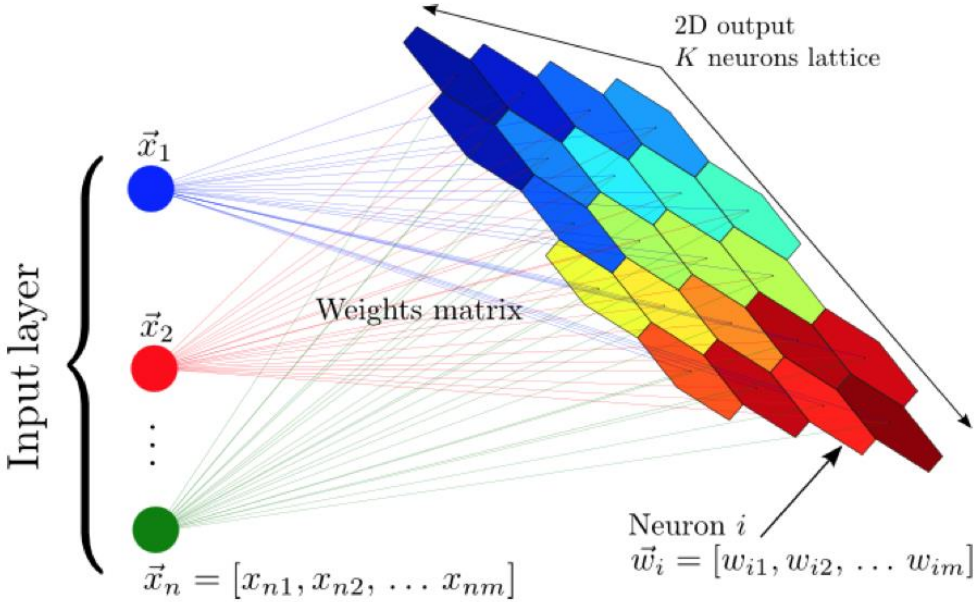
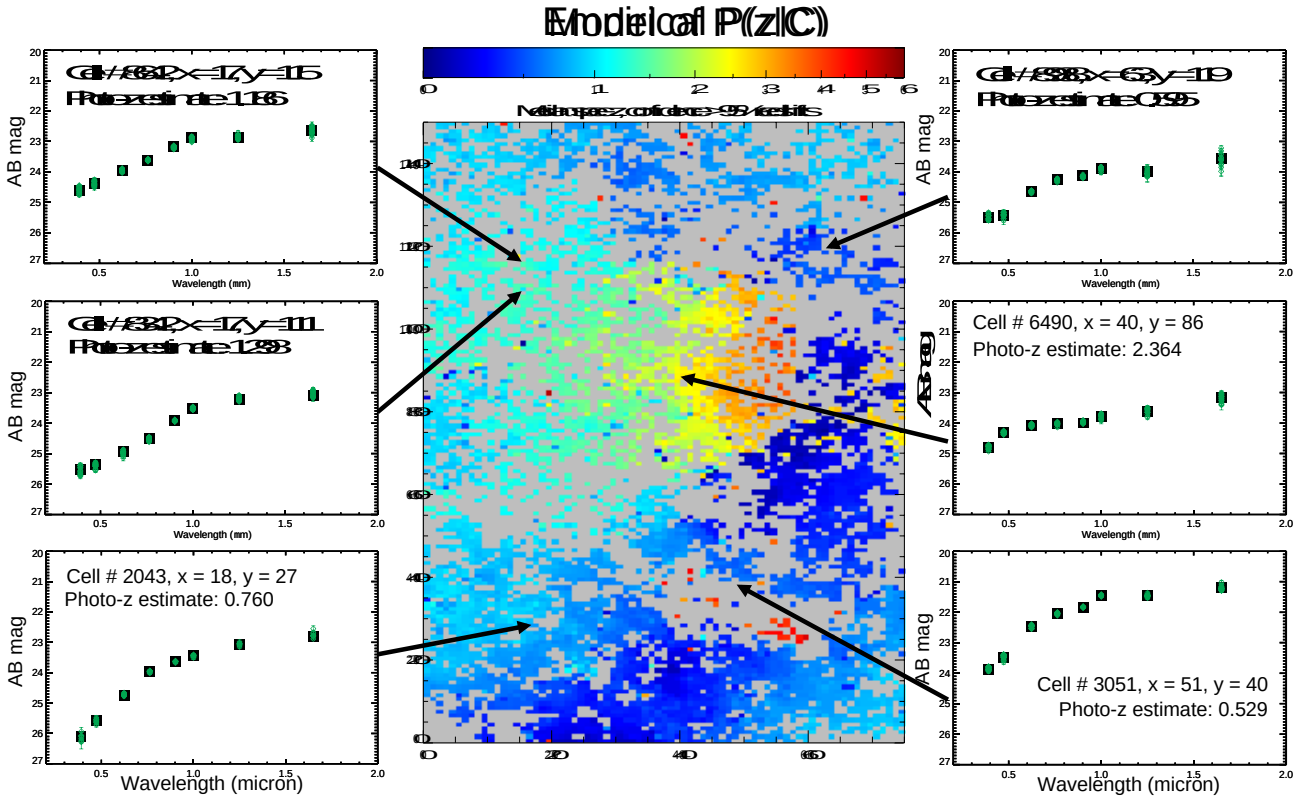


Illustration of the SOM (From Carrasco Kind & Brunner 2014)

Self-organized map of galaxy colors



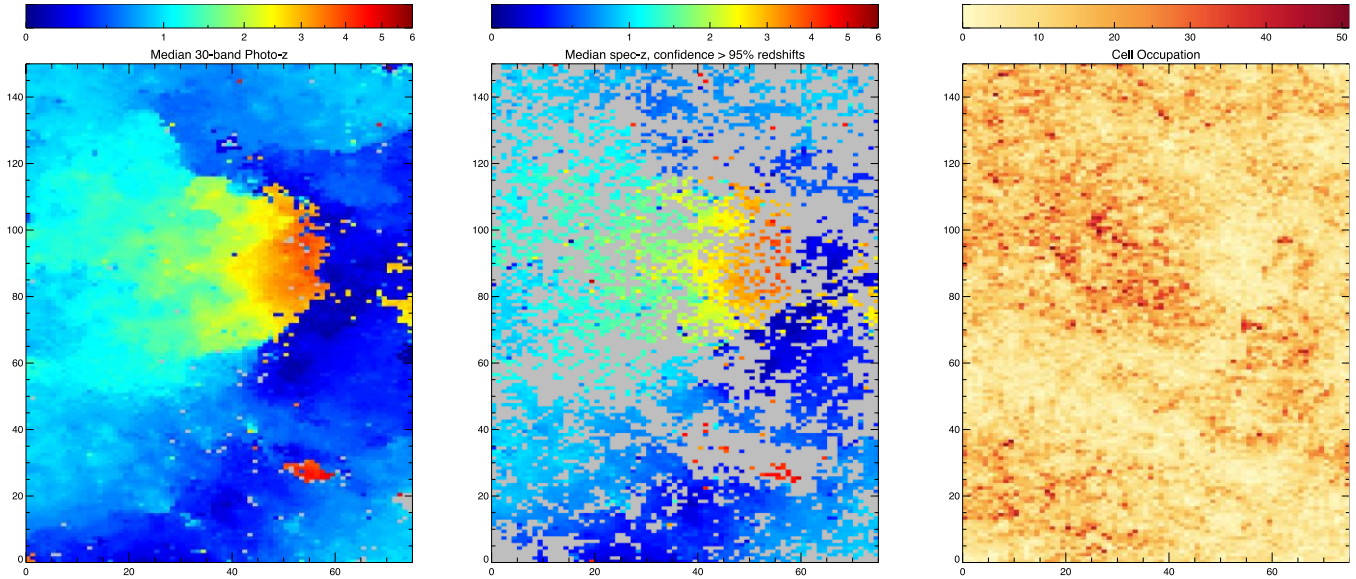
Masters et al. 2015, ApJ, 813, 53

C3R2: Mapping the galaxy P(z|C) relation

Complete Calibration of the Color-Redshift Relation (C3R2) Survey:

- Designed to “fill the gaps” in our knowledge of the color-redshift relation to Euclid depth
- Collaboration of Caltech (PI J. Cohen, 16 nights), NASA (PI D. Stern, 10 nights, PI D. Masters, 10 nights (2018A/2018B)), the University of Hawaii (PI D. Sanders, 6 nights), and the University of California (PI B. Mobasher, 2.5 nights), European participation with VLT (PI F. Castander)
  - Multiplexed spectroscopy with a combination of Keck DEIMOS, LRIS, and MOSFIRE and VLT FORS2/KMOS targeting VVDS, SXDS, COSMOS, and EGS
  - DR1 published (Masters, Stern, Capak et al. 2017) with 1283 redshifts, DR2 (in prep) will bring total to >4000 redshifts, observations in 2017B and later will comprise DR3
  - New Hawaii program (H20) led by Dave Sanders will also contribute
- Currently a total of 44.5 Keck nights awarded (29.5 observed in 2016A-2017A, 5 nights each in 2017B/2018A/2018B)

C3R2 survey strategy



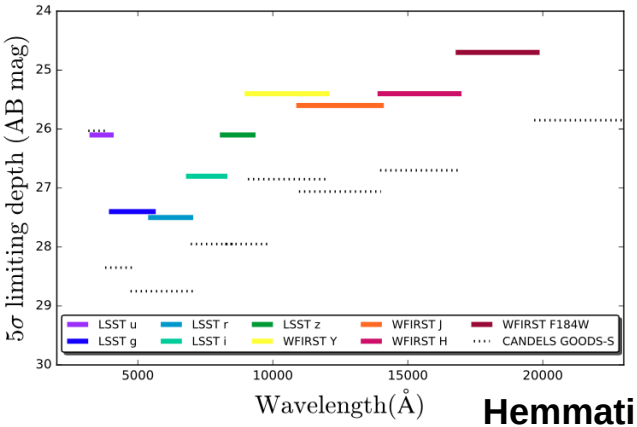
The ingredients of the survey:

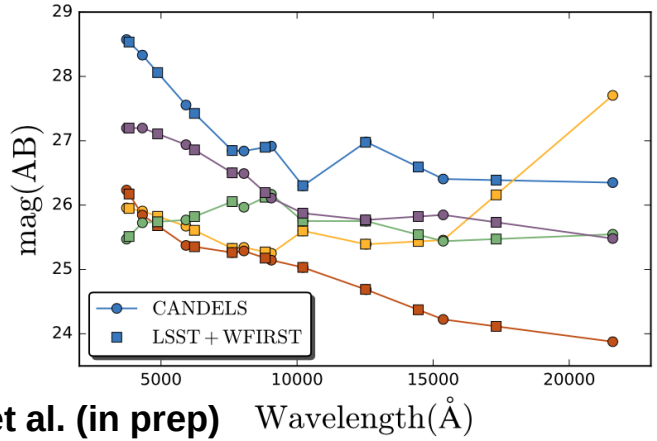
Left: Prior on galaxy properties across color space from deep, multiband data
Center: Shows parts of color space that have redshifts and that don't
Right: Density of sources across color space to Euclid depth

C3R2: The challenge of WFIRST

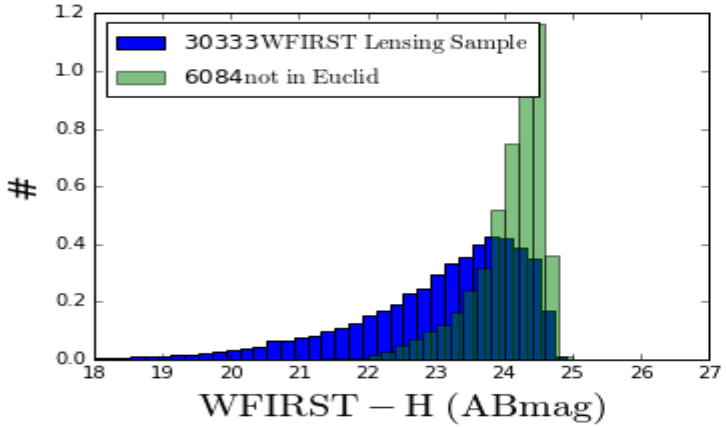
- C3R2 designed to map galaxy color space to *i*~25
  - Nominal Euclid weak lensing depth
- WFIRST shear sample (H-band selected) will be significantly fainter
- Need an analog to these photometric samples – CANDELS is only current dataset that can match the depth of LSST/WFIRST in optical-NIR
- It is small (~0.2 deg^2) and heterogeneous
  - Impacted by cosmic variance, shot noise
  - Best current option

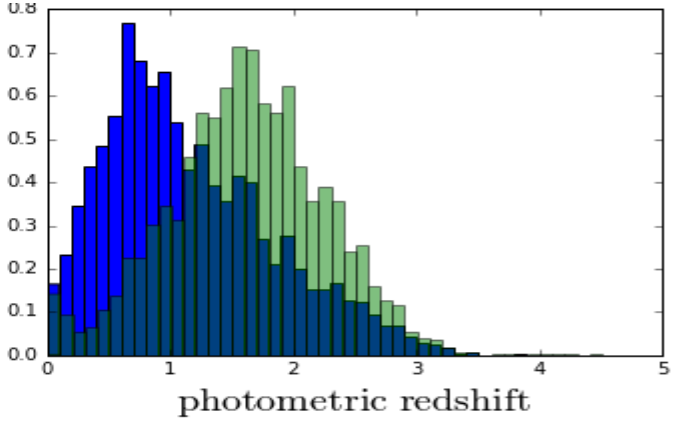
CANDELS interpolated to LSST+WFIRST



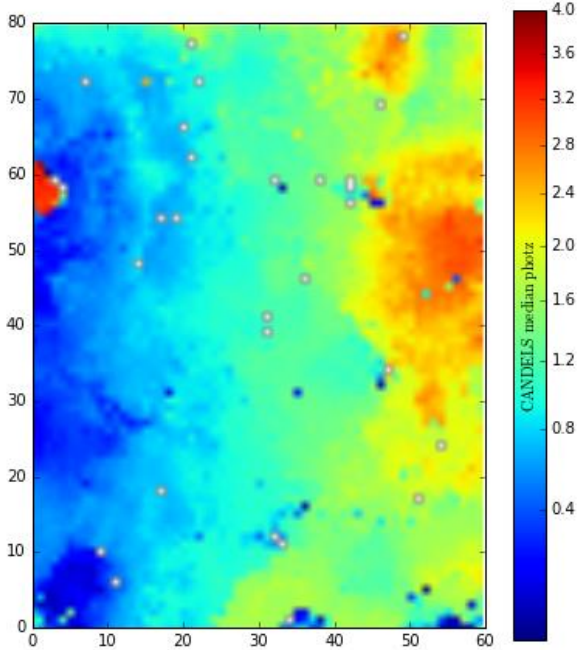


Hemmati et al. (in prep)

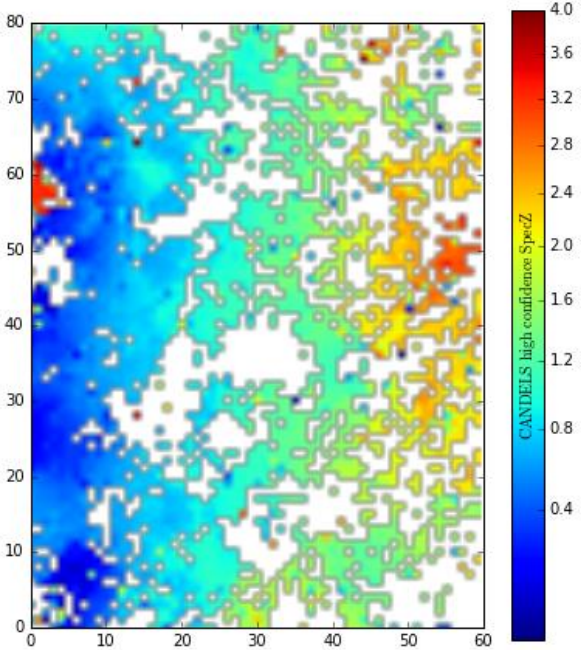




Redshifts on WFIRST-analog SOM



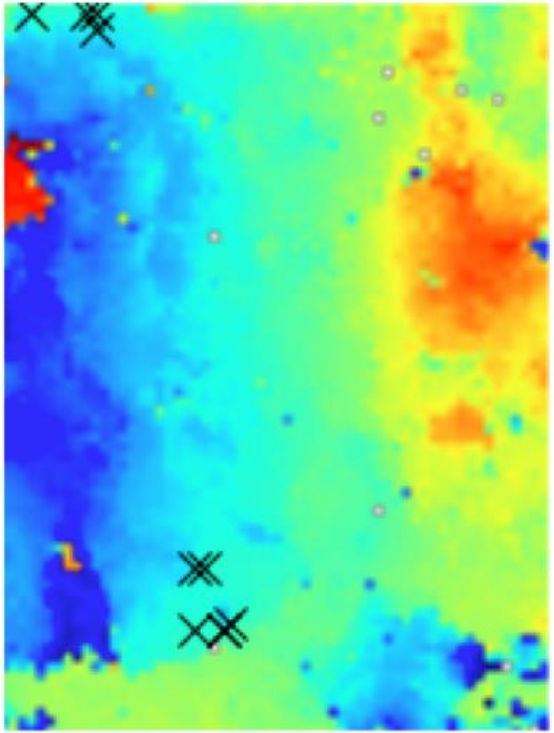
CANDELS median photo-z

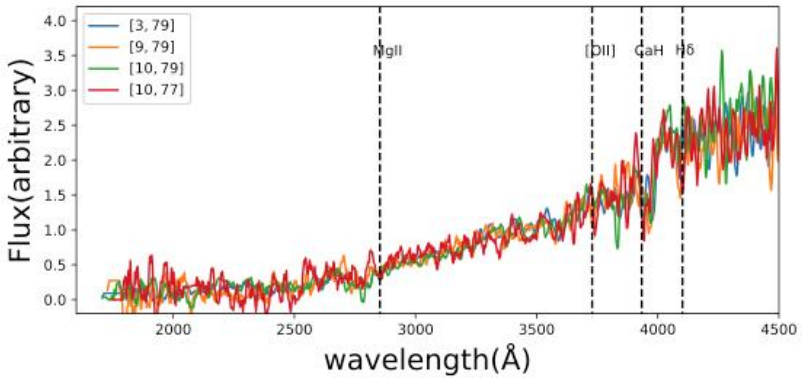


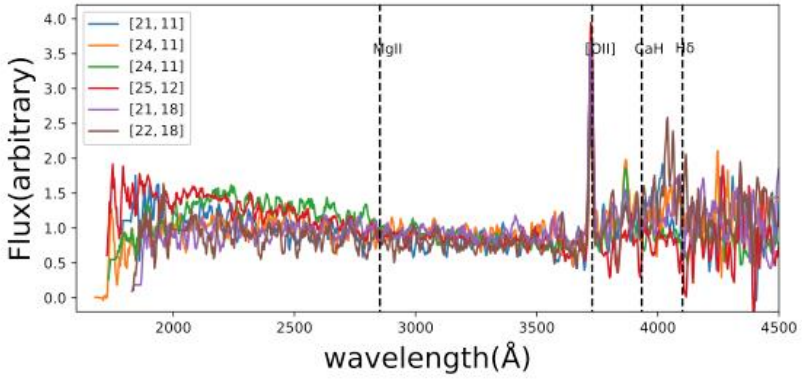
CANDELS median spec-z

Hemmati et al. (in prep)

Position on SOM predicts spectral properties

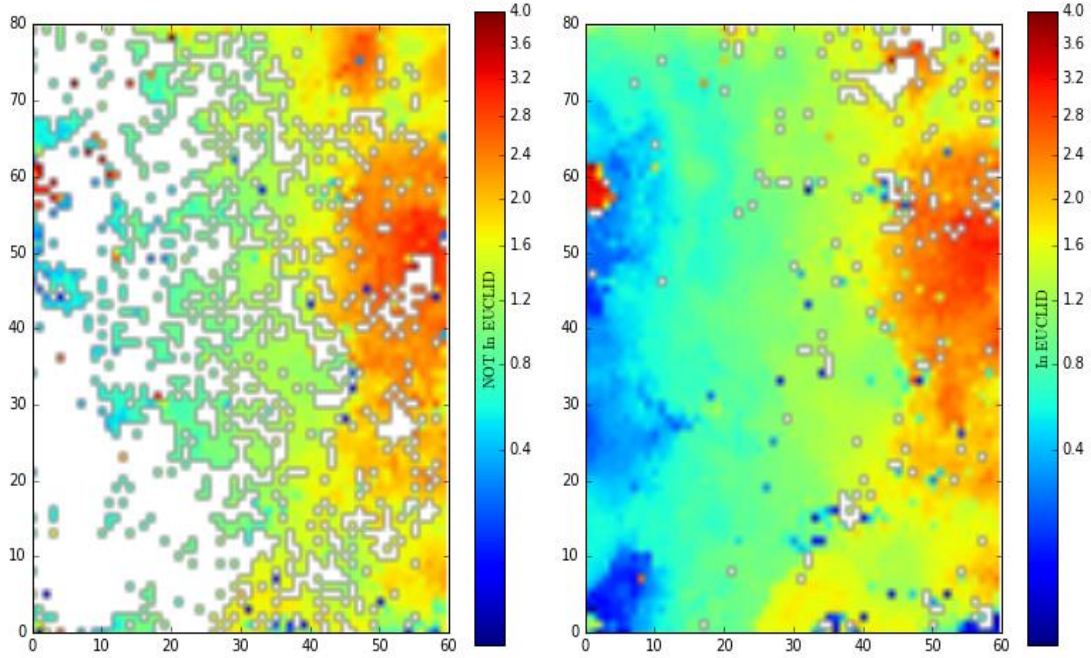






Hemmati et al. (in prep)

WFIRST “faint” vs. “bright” sample



Left: Distribution of WFIRST **faint** (i > 25) sample on SOM; fills ~50%
Right: Distribution of WFIRST **bright** (i < 25) sample; most cells filled

Key issues for WFIRST photo-z calibration

- Do faint galaxies that share colors with brighter galaxies have the same redshift?
  - i.e., is there are meaningful luminosity prior when using ~7 colors spanning optical-NIR
  - Do we require lots of spectroscopy of very faint sources to demonstrate the answer?
- WFIRST-faint sample peaks around z~2 and consists of optically very faint sources
  - Near-IR sensitivity likely needed for secure redshifts
- Fiber spectrographs on Keck/TMT could help calibrate this sample

Keck/TMT fiber spectrograph contribution

Ideal characteristics:

- High multiplexing
- High throughput
- Medium (R>2000) resolution
- Sensitivity in near-IR (at least bluer NIR)
  - Redshifts from rest-frame emission lines to z~3
- Optical spectrographs would generally need to get rest-UV continuum absorption features for high-z calibration
  - Lyα line problematic